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Canadian Science Advisory Secretariat (CSAS)

Research Document 2013/068

Central and Arctic Region

Information to support an updated stock status of commercially harvested Arctic Char (*Salvelinus alpinus*) in the Cambridge Bay region of Nunavut, 1960–2009

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September 2013

Canada

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

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ISSN 1919-5044

Correct citation for this publication:

Day, A.C. and Harris, L.N. 2013. Information to support an updated stock status of commercially harvested Arctic Char (*Salvelinus alpinus*) in the Cambridge Bay region of Nunavut, 1960–2009. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/068. v + 30 p.

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ABSTRACT

Harvest (1960 to 2009) and biological data (1971 to 2009) are presented for the commercial Arctic Char (*Salvelinus alpinus*) fishery of Cambridge Bay, Nunavut. Various aspects of Arctic Char biology and their response to harvest are also assessed and summarized. Since the inception of the fishery in 1960, total commercial landings from the seven primary fisheries (Lauchlan (Byron Bay), Halovik (Thirty Mile), Surrey (Paliryuak), Ekalluk, Jayco, Ellice and Perry rivers), have averaged 41,290 kg round weight per year with total landings exceeding 2,000,000 kg round weight from 1960 to 2009. The subsistence harvest of char is substantial, estimated to equal approximately half that of the commercial harvest. Trends in mean age and fork length appear stable although they exhibited a high amount of annual variation which was somewhat synchronous among locations. Several of the fisheries demonstrated increasing trends in mean round weight and mean condition factor. Pooled maturity data suggested that 64 % of females and 70 % of males harvested by the fishery were immature. However, recent maturity assessments at other locations suggest this may not be accurate and a higher percentage of mature fish are actually being harvested. For the examination of long term growth trends, length at age was analyzed separately for each of four decadal periods and for all fisheries, growth rate did not differ among these periods. All of the primary stock complexes were considered to have a low level of risk of overexploitation under current harvest regimes, with the exception of the Ellice River stock complex. The Ellice River stock complex is considered to have a moderate level of risk of overexploitation due to a decline in mean age, a consistent increase in mean condition factor and round weight, and a faster growth rate in comparison to growth rates of char from other fisheries. This level of risk, however, is lessened by the fact that this river has not been fished since 1999. Overall, the Cambridge Bay Arctic Char fishery and its supportive stocks are considered stable and fished at or below their sustainable rates of harvest.

Renseignements pour appuyer la mise à jour de l'état du stock d'ombles chevaliers récoltés dans la baie de Cambridge (Nunavut) de 1960 à 2009

RÉSUMÉ

Ce document présente des données biologiques sur l'omble chevalier (*Salvelinus alpinus*) (1971-2009) et sur la pêche commerciale (1960-2009) de cette espèce dans la baie de Cambridge, au Nunavut. Différents aspects de la biologie de l'omble chevalier ainsi que sa réaction à la pêche y sont également évalués et résumés. Depuis que l'on a commencé à pêcher cette espèce en 1960, la moyenne annuelle des débarquements commerciaux totaux des sept principales pêches (Lauchlan (Byron Bay), Halovik (Thirty Mile), Surrey (Paliryuak), Ekalluk, Jayco, rivières Ellice et Perry) s'est chiffrée à 41 290 kg (poids brut), totalisant plus de 2 millions de kg (poids brut) pour la période allant de 1960 à 2009. La pêche de subsistance de l'omble chevalier est importante; on l'estime à environ la moitié de la pêche commerciale. Les tendances des moyennes d'âge et de longueur à la fourche semblent stables bien qu'elles présentent bon nombre de variations annuelles, qui se sont révélées synchrones entre les emplacements. Plusieurs de ces pêches ont démontré une tendance à la hausse du poids brut moyen et du coefficient de condition moyen. Les données combinées sur la maturité indiquent que 64 % des ombles femelles et 70 % des ombles mâles qui ont été pêchés étaient immatures. Toutefois, de récentes évaluations de la maturité dans d'autres emplacements donnent à penser que ces chiffres sont inexacts et qu'en réalité un plus grand pourcentage de poissons adultes est pêché. Afin d'examiner les tendances à long terme de la croissance, la longueur selon l'âge a été analysée séparément pour les quatre décennies. Pour toutes les pêches, le taux de croissance n'était pas différent d'une décennie à l'autre. Tous les complexes de stocks ont été considérés comme comportant un faible risque de surexploitation en vertu des régimes de pêche existants, à l'exception de celui de la rivière Ellice. Le complexe de stocks de la rivière Ellice comporte un risque modéré de surexploitation en raison du déclin de l'âge moyen, de la hausse constante du coefficient de condition et du poids brut moyens et d'un taux de croissance de l'omble plus rapide par rapport à celui des autres pêches. Cependant, ce niveau de risque est amoindri par le fait que la rivière n'a fait l'objet d'aucune pêche depuis 1999. Dans l'ensemble, la pêche de l'omble chevalier dans la baie de Cambridge et ses stocks complémentaires sont considérés comme étant stables, et l'exploitation de l'espèce est égale ou inférieure aux taux de prélèvements durables.

INTRODUCTION

The Arctic Char, *Salvelinus alpinus* (L.) is distributed across the Canadian Arctic, including the islands of the Arctic Archipelago. It occupies many rivers and lakes on Victoria Island, near the community of Cambridge Bay, as well as on the mainland to the south of this island. Typically, anadromous (sea-run) Arctic Char are most sought after for subsistence and commercial use. In most cases, harvests of upstream migrant char occur in mid- to late-August and early September at river mouths with gillnets or in the rivers themselves with weirs. Harvest of downstream migrant char also occurs at several waterbodies in the region. Arctic Char have remained important for residents of Cambridge Bay and currently five waterbodies are primarily harvested for commercial purposes. A description of the history of commercial harvest in the Cambridge Bay area is provided below.

THE FISHERY

Prior to the onset of the commercial fishery it is likely that all river systems in this area were fished for subsistence purposes. Data on subsistence harvest, however, are very limited. The only published subsistence data for this area come from the Nunavut Wildlife Harvest Study (Priest and Usher 2004) which reported the number of Arctic Char harvested from June 1996 to May 2001. During this period, annual numbers of subsistence harvesters of char varied between 23 and 55 and annual harvests of Arctic Char varied between 1,437 and 12,435 with a mean of 6,461 char per year (Preist and Usher 2004). Assuming that the average size of a char from the subsistence harvest is similar to the average commercially harvested size (~ 3.5 kg), the annual char subsistence harvest may have been approximately 22,600 kg or about half the size of the annual commercial harvest. This estimate assumes that the mesh size used by subsistence harvesters is similar to that used by the commercial fishery, an assumption supported by the Ekaluktutiak Hunters and Trappers Organization (EHTO) of Cambridge Bay. It is likely however, that the subsistence harvest estimated from this study is an overestimate as community members have suggested that some commercial harvest was likely included in their totals.

The early history of this fishery is described in detail by Abrahamson (1964) and Barlishen and Webber (1973). Figure 1 shows the commercial fisheries in the Cambridge Bay area. Quotas and harvests from the primary fisheries are presented in Table 1. Commercial fishing first began at Cambridge Bay in 1960, with a gillnet operation on Freshwater Creek. At that time, a test-fishery was also conducted at the Ekalluk River (Barlishen and Webber 1973). In 1962, the commercial fishery was relocated to the mouth of the Ekalluk River, where it empties into Wellington Bay. As the fishery developed, other sites were fished, including the Paliryuak (Surrey), Halovik (Thirty Mile), Lauchlan (Byron Bay) and the Jayco rivers. Additionally, commercial fishing eventually expanded to two mainland systems, the Ellice and Perry rivers, the latter of which was only fished for six years. Initially, an "area" quota was established for Wellington Bay, but the decline in the fishery at Ekalluk River, where most of the fishing took place, necessitated the establishment of "river-specific" quotas to distribute fishing effort. Over the years, other sites were periodically fished, including Dease Point (Kulgayuk River), Padliak Inlet, Elu Inlet, Starvation Cove and HTA Lake (Takyoknitok). Commercial fishing sites are located at or near the mouths of various rivers in the area, and target either the downstream run in spring or the upstream run in fall. Initially, gillnets of various mesh sizes were used but, ultimately, a minimum mesh size was established at 140 mm (5.5 inches). Since the inception of the fishery in 1960, commercial landings from the seven primary fishing sites (Ekalluk, Ellice, Halovik, Lauchlan, Jayco, Perry and Paliryuak rivers) have averaged 40,900 kg round weight per year with approximately 2,000,000 kg of Arctic Char harvested (Table 1).

In recent years there has been a change in fishing gear from gillnets to weirs for several of the Cambridge Bay area fisheries (Table 2). Prior to 1994, gillnets were used exclusively for the harvest of char from the Halovik and Jayco rivers but from 1994 to the present, these two fisheries have been conducted with weirs except for the Halovik River in 1995 and 2001 and the Jayco River in 1995. Char have been harvested from HTA Lake by weir since this fishery began in 1988. From the onset of the Cambridge Bay commercial Arctic Char fishery through to the present, harvest has been conducted exclusively with gillnets at the Ellice, Paliryuak, Lauchlan and Ekalluk rivers fisheries with the exception of 1994 and 1995 when weirs constructed of netting material were used at the Ekalluk River. All other Cambridge Bay weir fisheries have used conduit weirs described by Kristofferson et al. (1986). The history of each fishery is elaborated below.

Freshwater Creek

The first commercial fishing effort, at Freshwater Creek (which flows by the community of Cambridge Bay) in 1960, produced a harvest of about 2,500 kg of Arctic Char. In 1961, harvest increased to 7,850 kg from an increased quota of 10,500 kg. Due to evidence of a declining stock, and its primary importance as a subsistence fishery, commercial fishing ceased at Freshwater Creek in 1962.

Ekalluk River

In 1960 two families were sponsored to fish at the Ekalluk River for test-fishing purposes where 15,880 kg of Arctic Char were harvested (Barlishen and Webber 1973). After over-fishing at Freshwater Creek became apparent, the commercial fishery was relocated to the Ekalluk River in 1962 with a quota of 18,160 kg. From 1962-1966, the average annual harvest at the Ekalluk River was 14,570 kg. In 1967, an area quota (45,000 kg) was issued for the Wellington Bay area in an attempt to distribute fishing effort to other systems flowing into this bay (Paliryuak and Halovik rivers). In 1967, all fishing was concentrated at the Ekalluk River, with a harvest of 27,670 kg. In 1968, fishing occurred at the Ekalluk, Paliryuak and Halovik rivers, under the 45,400 kg area quota. The reported harvest for the Ekalluk River was 34,300 kg. In 1969, under the same area quota, 22,700 kg was harvested at the Ekalluk River. The average annual harvest at the Ekalluk River over this three year period was 28,200 kg, but the average weight of Arctic Char taken at the Ekalluk River was reported to have declined from 3.0 kg in 1967 to 1.4 kg in 1969. In comparison, the average weight of Arctic Char taken at Halovik River in 1969 was 3.2 kg. Consequently, the commercial fishery at Ekalluk River was closed in 1970 and remained so until 1973 when it was reopened under the original 18,160 kg quota. In 1973, 9,630 kg were harvested and averaged fish size was 2.7 kg per fish. The quota was reduced to 11,350 kg in 1974 and remained at that level through 1978 during which time harvest averaged 13,790 kg. The quota was increased to 14,500 kg in 1979, and the average harvest at this site over the years 1979 to 1990 was 14,290 kg. The Ekalluk River was not fished in 1991 or 1992, for various reasons including declining size of Arctic Char and declining prices for the product. A small harvest of 1,480 kg was taken in 1993 under a quota of 7,500 kg. From 1994 to 2003, a shared quota of 20,000 kq for the Ekalluk and Paliryuak rivers was set. In 1994, 1,640 kg were harvested from the Ekalluk River. An experimental weir, located at the outlet of Ferguson Lake, was used during both 1993 and 1994. The plan was to hold char alive in a pen until transport to market could be assured. There was some success in getting a fresh product to market using this technique. Although the fishery was opened in 1995 with the 20,000 kg quota, only 4,665 kg were harvested that year (all from the Ekalluk River). In 1996, however, 10,210 kg were harvested using the traditional gillnets set near the mouth of the river, 14,328 kg were taken in 1997, and 19,825 kg were taken in 1998. From 1999 to 2002 and in 2004 both the Ekalluk and Paliryuak rivers were harvested under shared quotas. Annual harvest for the period 1999 to

2009 from the Ekalluk River averaged 14,425 kg. Harvest at the Ekalluk River in 2009 was reported to be 12,666 kg.

Paliryuak (Surrey) River

Commercial fishing first took place here in the spring of 1968. The harvest that year was 6,470 kg, under the Wellington Bay area quota of 45,400 kg. It was not fished in 1969, but a harvest of 5,880 kg was reported for 1970. Fishing here ceased until 1977, when a harvest of 3,260 kg was reported under a 4,500 kg quota assigned to the Paliryuak River. The quota was increased to 6,800 kg in 1978, with a reported harvest that year of 8,420 kg. The quota was increased again in 1979 to 9,100 kg. The average harvest from 1979 to 1993 was 8,880 kg at the 9,100 kg quota. In 1994, the quota was rationalized with the Ekalluk River quota, based on the results of tagging studies that indicated most char taken in the Paliryuak fishery were from Ekalluk River stocks. No fishing took place at this site from 1994 to 1998 inclusive. The average annual harvest from 1999 to 2009 inclusive (excluding 2003 when no fishing occurred) was 7,441 kg. Harvest at the Paliryuak River in 2009 was 8,657 kg.

Halovik (Thirty Mile) River

Commercial fishing began here in 1968, and took place in spring, similar to the fishery at Paliryuak River. An average harvest of 16,290 kg was reported from 1968 to 1971 under the Wellington Bay area quota of 45,400 kg. In 1972, a quota of 9,100 kg was assigned to the Halovik River and harvest from 1972 to 1973 averaged 4,200 kg. Due to declining catches and size of Arctic Char in the catch, the fishery was closed from 1974 to 1975, inclusive. The fishery resumed in 1976 under the 9,100 kg quota, and 2,780 kg were harvested. In 1977, the quota was reduced to 4,500 kg, and the average catch for 1977 and 1978 was 5,179 kg. The quota was increased in 1979 to 6,800 kg, and catches averaged 6,850 kg for the period 1979 to 1993. This fishery has been harvested by weir in the fall from 1994 to the present with a 5,000 kg quota. Average annual harvest for the period 1994 to 2009 inclusive was 6,045 kg. Harvest at the Halovik River in 2008 was 3,908 kg. . Harvest at the Halovik River in 2009 was 4,555 kg.

Lauchlan River (Byron Bay)

The Lauchlan River was first fished for commercial purposes in 1970, although a harvest of 2,270 kg was reported in 1963 with no quota assigned. This site was also included under the initial Wellington Bay area quota of 45,400 kg, and during the years 1970 and 1971, an average of 10,736 kg of Arctic Char was taken there each year. This fishery takes place in spring, and was assigned a site-specific quota of 18,160 kg in 1972. Average annual harvest for 1972 and 1973 was 15,326 kg. The quota was reduced to 11,350 kg in 1974, and harvest fell to 8,125 kg that year. As a consequence, the fishery was closed during 1975 and 1976. It reopened in 1977 under a reduced quota of 6,800 kg, and average annual harvest for 1977 and 1978 was 5,028 kg. The quota was increased to 9,100 kg in 1979, and average annual catch from 1979 to 1993 was 9,230 kg. This site was not fished in 1994 but was opened in 1995 under a reduced quota of 2,400 kg. Harvest for 1995 to 1999 inclusive averaged 1,772 kg. No fishing took place in 2000 but 446 kg were harvested in 2001. No fishing took place in 2002. With the exception of years 2000 and 2002, annual harvest for the period 1999 to 2009 averaged 3,843 kg. The river was not commercially fished in 2009 given the costs associated with the distance from Cambridge Bay.

Jayco River

The Jayco River was first fished commercially in 1975. Average catch from 1975 to 1977 was 8,410 kg, under a quota of 6,800 kg. The quota was increased in 1978 to 11,350 kg and harvest that year was reported to be 13,442 kg. The quota was increased to13,600 kg in 1979, and annual catches averaged 12,264 kg from 1979 to 1990. This location was occasionally fished in

spring and fall, with the quota being shared between the fishing seasons. However, in 1980, the harvest was taken by experimental weir (Kristofferson et al.1986) during the fall upstream run, and, for the most part, harvest since then has been by weir. In 1991, the quota was increased to 15,600, but harvest, by gillnet that year, was only 2,226 kg. Ice forming on the weir caused it to collapse. No fishing took place in 1992 due to low prices, but resumed in 1993 with 15,411 kg harvested. The quota was increased to 17,000 kg in 1994 and has remained at this level since. The average annual harvest at this site from 1994 to 2009 inclusive was 12,531 kg. In 2009, 6,514 kg of Arctic Char where harvested at this location. Harvesting the full quota has been difficult at this site because the fall upstream migration of char occurs relatively late (early September) when ice conditions have often interfered with fishing.

Ellice River

Commercial fishing began at this mainland site in the fall of 1971. The quota that year was set at 22,700 kg and a harvest of 12,820 kg was reported. The quota was reduced to 11,350 kg for 1972, and catches for 1972 to 1975 averaged 9,269 kg. In 1976, the quota was increased to 13,600 kg and the average catch from 1976 to 1978 was 14,199 kg. The quota was reduced to 9,100 kg in 1979, due to a decline in the size of Arctic Char in the catch. The average harvest from 1979 to 1984 was 7,736 kg. The quota was further reduced to 4,500 kg in 1985 and the average annual catch from 1985 to 1987 was 4,768 kg. The quota was then increased to 6,000 kg in 1988 and average annual catch for 1988 to 1990 was 6,295 kg. The quota was increased again in 1991, to 8,000 kg and average annual harvest from 1991 to 1996 was 6,860 kg, excluding 1992 when no fishing occurred. With the exception of 1999, when 4,497 kg of char were harvested, there has been no fishing at this site since 1997.

Perry River

The Perry River, located on the mainland east of Ellice River, was first fished for five consecutive years starting in fall of 1977. Average harvest from 1977 to 1980 was 6,724 kg, under a quota of 11,350 kg. In 1981, the quota was reduced to 6,800 kg, due to declining size of Arctic Char in the catch. Harvest that year was reported to be 2,836 kg. The quota was further reduced to 4,500 kg in 1985 but no fishing took place under that quota. In 1991, the quota was increased to 6,500 kg and a harvest of 600 kg was reported. The site has not been fished since, primarily due to the cost of transporting the catch to the community of Cambridge Bay, and inclement weather often experienced there in fall.

Other Fishing Sites

Over the years, other sites were periodically fished, including Dease Point (Kulgayuk River) on the mainland for 8,890 kg (9,100 kg quota) in 1972, 3,020 kg (22,700 kg quota) in 1974, and 1,170 kg (20,400 kg quota) in 1976. A harvest of 3,853 kg was reported in 1991 under a 4,000 kg quota and a harvest of 3,120 kg was reported in 1993. Padliak Inlet was fished in 1977 for 880 kg (2,270 kg quota). Elu Inlet, on the mainland, was fished for 2,620 kg in 1977 and 260 kg in 1978, under a quota of 2,270 kg. Starvation Cove, on the south coast of Victoria Island, west of Cambridge Bay, was fished for 6,370 kg of Arctic Char in 1977, although no quota was assigned for that location.

An experimental fishery took place for a number of years at a site called HTA Lake (Takyoknitok), on the southeast coast of Victoria Island. A weir was used there and the average harvest for the period 1988 to 1991 inclusive was 1,558 kg under a quota of 1,500 kg. This quota was increased to 2,500 kg in 1993, and 3,000 kg in 1999. No fishing was reported for 1992 but the average harvest for 1993 and 1994 was 2,302 kg. No fishing was reported in 1995 but the harvest in 1996 was 2,685 kg. No fishing was reported for 1997 or 1998, but the 1999

harvest was 2,847 kg. No fishing was reported in 2000. Fishing has not taken place there since 2001 when 2,988 kg was harvested.

METHODS

BIOLOGICAL DATA COLLECTION

This assessment was based primarily on data obtained from the commercial plant sampling program. This annual sampling program, in which commercially harvested char are sampled at the Cambridge Bay fish plant (Kitikmeot Foods Ltd.), facilitated the collection of fork length (± 1 mm), dressed weight (head on, viscera and gills removed; ± 50 g) and aging structures for the six primary Cambridge Bay fisheries (Ekalluk, Lauchlan, Halovik, Paliryuak, Ellice and Jayco rivers). The plant sampling protocol is described by Kristofferson and Carder (1980). Sample dates and type of commercial fishing gear used for each year of the fishery in which plant sampling was conducted are given in Table 2.

In this assessment, the Cambridge Bay Arctic Char commercial fishery is being evaluated to determine the effects of fishing on stocks of Arctic Char in this area. The assessment focuses on the sites with long term datasets. The response of char to commercial harvest is evaluated using age in years, round weight, fork length and condition. All aging of char otoliths was done by one person following the method of Nordeng (1961). All analyses and graphics were done using SAS (1989, 1990). When round weights were not measured in the field or fish plant, they were estimated from dressed weights using the river-specific regressions outlined by Day and de March (2004). Sampling for sex and maturity stage was conducted on occasion but not annually because char were dressed (viscera and gills removed) prior to shipping to the fish plant where biological sampling occurred. When possible sex and maturity stage were assigned via visual observation of the gonads and a numerical grading system applied as described by McGowan and Low (1992)

Gillnets of commercial mesh size (140 mm stretched mesh) were periodically used for fishery-independent sampling of biological data either in place of commercial harvesting or in conjunction with it. Sampling in this manner was conducted at the Ekalluk River (1972, 1975, 1978, 1980, 1988, 1991, 1992, 2005, 2006), the Halovik River (2006), the Paliryuak River (1980) and at the Jayco River (1975, 2005). Additionally, on occasion, experimental weirs were used to collect fishery independent biological information on Arctic Char from some of these fisheries. Specifically, weir have been used for the collection of biological data at the Ekalluk River (1975, 1979, 1980, 1981, 1983), the Halovik River (1981), the Lauchlan River (1983) and at the Jayco River (1975, 1980, 1981).

Other research has been undertaken on the Arctic Char stocks in this area throughout the history of this fishery including 1) weir enumerations of fall upstream migrations, 2) tagging and 3) research on genetic stock structure and homing to natal spawning grounds.

RESULTS AND DISCUSSION

ABUNDANCE

Catch-per-unit-effort (CPUE) data, an index of abundance commonly used in fisheries science, are not available for Cambridge Bay commercial char fisheries. This is unfortunate because it limits the amount of information that could be generated from modeling exercises such as Virtual Population Analysis (VPA). It may be possible to find information on the number of days each fishery was prosecuted to fill its quota from Cambridge Bay fish plant records. This should

be investigated as if these CPUE data were available they may serve as an index of abundance for the Arctic Char stocks.

Abundance information is limited to single year weir enumerations for the upstream migrations of four commercially fished Cambridge Bay sites (Ekalluk, Jayco, Halovik and Lauchlan rivers) and three upstream weir enumerations of Freshwater Creek which has not been commercially fished since 1961 (Table 3). The 1980 enumeration at Jayco River was considered incomplete because of ice conditions so is not comparable to the 1981 count. There is likely a significant amount of annual variation in upstream weir counts, given Arctic Char biology (e.g., overlapping generations, iteroparity) and the complexity of Arctic Char systems in the region. Consecutive annual assessments at one or more fishing sites via weir enumeration should be considered for future assessments of annual variation in abundance.

Abundance estimates combined with average weights of Arctic Char sampled during upstream weir enumerations were used to crudely estimate exploitation rates for fisheries with enumeration data. This was done by applying an estimated total biomass (the number of fish enumerated x the average weight of enumerated fish) against the biomass of Arctic Char harvested to determine an approximate rate of exploitation. For example, at the Ekalluk River in 1979, 183,203 fish were enumerated with an average overall weight of 2.01 kg (estimated from 2,123 fish). That year, 15,806 kg of Arctic Char were commercially harvested resulting in an exploitation rate of 4.1% of the available biomass. Applying these same calculations resulted in exploitation rates 4.2%, 11.1% and 34% of the total available biomass for the Jayco (1981), Halovik (1981) and Lauchlan (1983) rivers respectively. To our knowledge, these estimated exploitation rates may represent the only information available on sustainable harvest rates of anadromous Arctic Char populations.

AGE TRENDS

Mean ages were variable among years and did not show consistent trends (i.e., increasing or decreasing mean age over the sampling period) suggesting stability in response to harvest (Figure 2). Peaks and troughs in mean age plots were somewhat synchronous for the Wellington Bay fisheries but much less so for the Ellice and Jayco river fisheries. For example, all Wellington Bay fisheries demonstrated a relatively large peak of older ages centered around 1985 and 1986 which suggests that annual recruitment of char in this area is highly variable and driven by large scale abiotic factors.

Day and de March (2004) examined age trends as the presence of strong modal age classes and their findings are summarized and updated with data from 2004 to 2009 in Table 4. By definition, a strong modal age class was one that comprised ≥ 20 % of an annual plant sample. With respect to the Ekalluk River plant samples, between 1971 and 2009, the number of strong modal age classes decreased slightly from ages 12-16 in the early years of the fishery to ages 11-14 in more recent years. In the Ellice River, strong 12 and 13 year old modal age classes are missing in recent years. In the Halovik River, the catch was composed of modal age classes of 11-15 and has remained nearly constant through all fishing periods with the exception of the 1981-1990 period when older modes were present and younger modes were missing. In the Jayco River, the number of strong modal age classes decreased slightly from age 15-16 in early years of the fishery to age 11-14 in recent years. In the Lauchlan River, the presence of strong modal age classes has been similar among fishing periods between 1981 and 2009 with strong modes ranging from age 11 to 16. In the earlier period of 1971-1980, Lauchlan River samples had noticeably younger modes (8-14). Strong modal age classes of Paliryuak River char have remained relatively stable at 12-15 for fishing periods between 1981 and 2009 except from 1991-2000 although the fishery operated only five years during that period.

Based on temporal trends in average age and strong modal age classes, a level of risk of overexploitation, if harvest rates continue at current levels, was assigned to six Cambridge Bay fisheries (Table 4). Risk levels assigned to all fisheries were low with the exception of the Ellice River. This fishery was assigned a moderate level of risk based on its consistent decline in modal age to a point where plant samples taken during the 1990s were composed almost entirely of fish which were younger than the mean age of maturity of Cambridge Bay char (see Sex and Maturity section below). The moderate Ellice River level of risk is somewhat mitigated by the fact that it has been fished only once since 1999.

Relative risk assessments based on intrinsic stock productivity predicted from first age of maturity and growth rate, suggest that the Jayco river char stock is less productive and therefore, have a higher potential risk of overexploitation than do other stocks in the Cambridge Bay area (Roux et al. 2011). Trends in population parameters of these stocks, however, are stable and this potential would only be realized if harvest rates increased.

GROWTH RATES

Growth rates were examined by Day and de March (2004) as plots of mean fork length at age for data pooled for the period of 1971 to 2003 (Figure 3). Growth of char from Wellington Bay samples was similar among locations. Growth of char in Ellice River samples differed from other locations in that growth during the first 10 years of life was more rapid with five-year-old fish attaining fork lengths of approximately 500 mm compared to fork lengths of approximately 300 to 400 mm for five-year-old fish from other locations. Growth of Arctic Char in the Jayco River samples differed from other locations in that maximum size was approximately 700 mm compared to a maximum size of approximately 800 mm for other locations. For all locations, growth started to become asymptotic at approximately age 16 except for Ellice River samples where growth plots were linear without a pronounced asymptotic phase. Approximately 75 % of char growth in fork length occurred prior to the mean age of maturity (female: 14.1 years, male: 14.2 years).

Trends in growth rates for each location were examined as plots of mean fork length at age after data were pooled for each of four periods (1971-1979, 1980-1989, 1990-1999 and 2000-2009) (Figures 4, 5, 6). There was little difference among periods in mean length at age for any location, which indicated that growth rates remained relatively unchanged between 1971 and 2009. For several of the fisheries, (Ekalluk, Halovik, Jayco and Lauchlan), younger age classes were noted in harvests taken in earlier periods, 1971 to 1979 and 1980 to 1989, but were absent from harvests of later periods.

SIZE AND CONDITION TRENDS

Length

Mean lengths varied without trend providing no evidence for an impact in response to harvest (Figure 7). The trends were characterized by peaks and troughs which occurred during similar sampling years among the Wellington Bay and Jayco River fisheries but in this respect, were much less similar for the Ellice River fishery (Figure 7).

Weight

Mean round weight for char in the Ekalluk, Paliryuak, Lauchlan and Jayco rivers varied without trend providing no evidence for an impact in response to harvest (Figure 8). This finding may suggest stability in response to harvest and the annual variability may be caused by environmental fluctuations. Mean round weights of char increased throughout sampling years in the Halovik River and increased from 1987 onward in the Ellice River. The mean round weight

trends in all fisheries were characterized by peaks and troughs which occurred during similar sampling years among the Wellington Bay and Jayco River fisheries but in this respect, were much less similar for the Ellice River fishery.

Condition

Condition factor (K) was calculated as:

$$K = \frac{W \cdot 10^5}{L^3}$$

where W and L are the round weight (g) and fork length (mm) of each individual fish, respectively. Condition trends (Figure 9) closely mirrored trends for mean fork length, mean age and mean weight and were characterized by the same peaks and troughs. Mean round weight increases of Ellice and Halovik char samples, which occurred during a period when mean ages and fork lengths did not show a pronounced increase implied that condition had increased for these fisheries.

SEX AND MATURITY

For each of the six Cambridge Bay char fisheries described above, gonads from Arctic Char were assessed for sex and maturity stage via visual inspection of the gonads as described by McGowan and Low (1992) and the results were pooled for all locations and summarized in Table 5. These assessments were not done annually but rather, were done opportunistically when experimental netting, experimental weir assessment or the rare delivery of undressed char to the fish plant allowed for the examination of gonads. Almost all char delivered to the fish plant are eviscerated, therefore sex and maturity stage assessment of plant sample Arctic Char is rare.

Mean ages of immature char were 10.7 years (95 % Confidence Interval (C.I.) = 10.3–11.0) and 11.7 years 95 % C.I. 11.5–12.0) for females and males respectively. Mean ages of mature stages (current year spawners, ripe, spent and resting char) were similar for males (14.2) and females (14.1) and ranged from approximately 14 to 15.4 years (Table 5). The mean ages of immature char suggest that, on average, females mature approximately one year earlier than do males. The 95 % C.I. of mean age of immature male and female char did not overlap (Table 5). The ranges of mean age, length and weight of the different maturity stages of char, however, are very broad suggesting that some char may mature at a very young age and small sizes. It is noted that a large proportion of relatively old char were classified as immature indicating that many char may never mature prior to removal caused by natural and fishing mortality.

Sex and maturity stage analyses for pooled data suggest that approximately 64 % of female char and 70 % of male char in commercial Cambridge Bay harvests are immature. However, maturity assessment data were unbalanced across years because the majority of assessments occurred prior to 1990 when higher frequencies of immature fish were observed. Hence, pooling of data may be misleading. Recent maturity assessments done for the Halovik (2006) and Jayco (2005) River fisheries indicated that 100 % of female char harvested were mature in both rivers and 100 % of the male char from the Jayco River were mature (Table 6). These observations indicate that maturity rates of char have increased as the fishery developed. The stability in char population parameters observed for five of the six fisheries during earlier years of the fishery indicates that 1) the harvest of char prior to maturity did not adversely affect the sustainability of Cambridge Bay char fisheries at that time or 2) that there is little correlation between char production, recruitment and harvest and that other factors ultimately determine char abundance in the Cambridge Bay area.

MIGRATION AND SPAWNING SITE FIDELITY

Anadromous Arctic Char overwinter in freshwater systems and undertake downstream spring migrations to the sea for foraging purposes. Some individuals, however, may not migrate to sea the year that they spawn (Johnson 1989). These migrations (i.e., spring downstream migrations to the sea and fall upstream migrations to freshwater) are the target of the Cambridge Bay commercial fishery and are likely composed largely of char that are not current-year spawners (Johnson 1980). In the Nauyuk Lake system on the Kent Peninsula, Gyselman (1994) found that overall fidelity of Arctic Char to this system was quite low and that straying rates must be high. Gyselman reported that char tagged in Nauyuk Lake were recaptured in virtually every fishery in the area including those fisheries of Cambridge Bay. Conversely, spawning char demonstrate high fidelity to their natal spawning grounds (Alm 1951, LeCren and Kipling 1963, Frost 1963, Glova and McCart 1974, Gyselman 1994). Johnson (1980) stated that Nauyuk Lake char did not migrate to the ocean during the year in which they spawn. Therefore, char which will spawn in the current year have a very low vulnerability to harvest at marine fishing grounds. This low vulnerability is consistent with the low percentage of current-year spawners observed in samples of anadromous char from Cambridge Bay (Table 7).

Tagging studies conducted at the Ekalluk River in 1978 and 1979 and Starvation Cove in 1979 have been summarized by Kristofferson et al. (1984) and tagging studies later conducted at other commercial sites (Halovik, Surrey and Jayco rivers) are summarized by Dempson and Kristofferson (1987). These authors reported that Arctic Char were recaptured at all fishing sites in subsequent years, which included the Ekalluk, Paliryuak, Lauchlan and Halovik rivers and these results are consistent with the findings of other authors who reported low fidelity of non-spawning char to natal spawning grounds (Gyselman 1994). During open-water periods fish travelling long distances of up to 550 km have been documented from tag returns but this distance may not have been traveled in a single year (Gyselman 1994). Dempson and Kristofferson (1987) found that ocean migrations of both Labrador and Cambridge Bay char were influenced by many factors including local marine environmental conditions, availability of marine food resources, fish size, fish sex, maturation state and proximity to other river systems.

GENETIC STOCK STRUCTURE

Very limited data are available on the genetic stock structure of Cambridge Bay Arctic Char. The only study to date, which assessed variation in allozyme loci, found little variation among Arctic Char populations within and between river systems (Kristofferson 2002). This suggests that there may be a high degree of straying among systems and the harvests of Arctic Char at discrete fishing locations are composed of a composite or a mixture of populations. That is, fidelity to natal sites in the Cambridge Bay area is likely low and this fishery represents a mixed-stock fishery. Indeed this is also evidenced based on the tagging data discussed above.

Gyselman (1994) concluded from his research on anadromous Nauyuk Lake char that Arctic Char seem to be a good example of a "metapopulation". Hanski and Gilpin (1991, p. 7) define a metapopulation as "a set of local populations which interact via individuals moving among populations". Indeed, there seems to be a great deal of movement of individuals among populations of both Nauyuk Lake and Cambridge Bay char as indicated by Gyselman's (1994) findings that a large proportion Nauyuk Lake char never returned to the system and by the tagging results of Kristofferson et al. (1984) and Dempson and Kristofferson (1987) demonstrated that there was extensive movement of tagged char between river systems of Cambridge Bay. Dempson et al. (2004) reported that there was little intermixing among populations from the widely distributed management areas of Nain, Voisey and Okak which occur along 300 miles of Labrador coastline from Antos to Saglek Fiord. Cambridge Bay char populations demonstrate greater annual variability in size, age and year class strength than do

Labrador char population described by Dempson et al. (2004). Information presented in this report indicates that, although the Cambridge Bay char fishery is supported by a complicated mosaic of discrete char stocks, their annual variation in population parameters is very uniform among five of the six widely separated fishing and sampling sites. This suggests that Cambridge Bay char, like Nauyuk Lake char, are also a good example of a "metapopulation" and that the observed uniformity is due to mixing of individual char among populations.

THE PRECAUTIONARY APPROACH

Precautionary approach (PA) models have been designed to assess and prevent overfishing and/or to preserve the spawning stock biomass. PA model objectives may be implemented through measures such as the use of size selective gear, seasonal closures and area closures to protect immature fish and or the spawning stock biomass. Uncertainty about maturation, ages and sizes of Cambridge Bay char pose challenges to developing a PA model for this fishery because sampling for maturity status was temporally unbalanced. Furthermore, PA models require assessment data which allows for the prediction of stock size, spawner-recruit relationships or surplus biomass. These types of data (see *Abundance*) are not currently available for the Cambridge Bay fishery. Current levels of harvest are considered sustainable however, in the absence of information on stock size, it is extremely difficult to predict the sustainability of quotas. Surplus biomass show some promise for development of a PA and DFO is presently investigating the feasibility of this approach.

SUMMARY AND CONCLUSIONS

Over a 49 year period between 1960 and 2008, total commercial landings from six primary stock complexes in the Cambridge Bay area have averaged 40,900 kg round weight per year with total landings for this period equal to 2,004,062 kg round weight. Subsistence harvest is largely unknown but is estimated to be approximately half the size of the commercial harvest. The primary stock complexes are now harvested at the Ekalluk, Halovik, Lauchlan, Jayco and Paliryuak rivers. The impact of the Cambridge Bay fishery on its primary stock complexes, were examined in this report. An absence of decreasing trends in mean size and age and temporal stability in strong modal age classes was evident as was an apparent increase in maturity rate throughout the history of the fishery. It is thus concluded that these geographic stocks are being harvested at or below their optimal sustainable rate of harvest. This stability and resiliency to harvest has also been noted by Dempson et al. (2008) for north Labrador Arctic Char. One exception is noted for the Ellice River fishery for which sampled char have demonstrated a consistent decline in age, increase in mean weight and condition and faster growth during the first five to 10 years of life when compared to char from other stock complexes. This fishery is considered to have a moderate risk of over-exploitation, however this location has not been fished since 1999. Development of a PA model for the management of the Cambridge Bay char fishery will be challenging because the correlation of size, age and maturity is unclear and there is a lack of information on abundance and stock recruitment relationships. Until catch per unit CPUE data are collected routinely for this fishery, it will not be possible to estimate char abundance using advanced fisheries science models.

Future work should focus on additional weir enumerations to assess whether run sizes are temporally stable and thus whether exploitation rates have remained relatively constant over the past 15 years. It is recommended that research move forward attempting to resolve fine-scale population structure in this region and the contribution of putative populations to the mixed-stock fishery. Until that time, it is difficult to determine how many population are being harvested and to what degree. The sustainability of increased quotas could be tested by small and conservative incremental increases followed by the assessment of monitoring data and

feedback from resource users. This approach, termed 'adaptive co-management' should be considered as an alternative approach to management of this fishery as suggested by Kristofferson and Berkes (2005).

It is recommended that 1) consecutive weir enumerations be conducted to provide estimates of stock abundance and to assess its annual variability, 2) annual and site specific assessment of the subsistence harvest be conducted, 3) the underlying causes of recruitment variation be determined through further field studies and or modelling, 4) the plant sampling program be expanded to procure larger sample sizes, 5) research be done on the influence of climate on the production of pre-smolt char in lakes, 6) recent advances in genetic models, which describe discrete stock contribution to mixed stock fisheries, be incorporated into the assessment of this fishery, 7) the feasibility of using surplus biomass models for the estimation limit reference points of a PA model be investigated, and 7) the assessment of annual and site-specific fishing effort (CPUE) be attempted.

ACKNOWLEDGEMENTS

Many thanks to Gary Carder, Dale McGowan and Al Kristofferson for the research they conducted and publications they produced on the Cambridge Bay char fishery. Their historical knowledge, diligence and expertise have provided the majority of the background information for this report. We are indebted to Kitikmeot Foods of Cambridge Bay for their assistance with the plant sampling program and the Ekaluktutiak Hunters and Trappers Organization for their traditional knowledge and support of this program in Cambridge Bay. We are also grateful for the funding support from Nunavut Implementation Funds which has permitted Cambridge Bay char research. Thanks are extended to Brian Dempson for his continued support of char research in the Central and Arctic Region, his many publications on Arctic Char and for his significant input into Cambridge Bay and Pangnirtung char fishery RAP meetings. Drs. Marie-Julie Roux and Xinhua Zhu reviewed the manuscript. A.C. Day would also like to thank Dr. Darren Gillis of the Biological Sciences Department, University of Manitoba, for providing statistical and scientific advice and for his assistance with determining the applicability of various fisheries science models to the analysis of this fishery.

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TABLES

Table 1. Quota and harvest (kg round weight) history of the Cambridge Bay commercial Arctic Char (Salvelinus alpinus) fishery. NQ = No Quota, NF = Not Fished.

Year	Ekalluk		Paliryuak		Halovik		Lauchlan		Ellice		Perry		Jayco		Source[a]
	Quota (kg)	Harvest (kg)	Quota (kg)	Harvest (kg)	Quota (kg)	Harvest (kg)	Quota (kg)	Harvest (kg)	Quota (kg)	Harvest (kg)	Quota (kg)	Harvest (kg)	Quota (kg)	Harvest (kg)	
1960	NQ	15876[b]	NQ	NF	NQ	NF	NQ	NF	NQ	NF	NQ	NF	NQ	NF	Kristofferson and Carder 1979
1961	NQ	NF	NQ	NF	NQ	NF	NQ	NF	NQ	NF	NQ	NF	NQ	NF	Kristofferson and Carder 1980
1962	18160	5765	NQ	NF	NQ	NF	NQ	2268[c]	NQ	NF	NQ	NF	NQ	NF	Kristofferson and Carder 1980
1963	18160	13874	NQ	NF	NQ	NF	NQ	NF	NQ	NF	NQ	NF	NQ	NF	Kristofferson and Carder 1980
1964	18160	15504	NQ	NF	NQ	NF	NQ	NF	NQ	NF	NQ	NF	NQ	NF	Kristofferson and Carder 1980
1965	18160	20865	NQ	NF	NQ	NF	NQ	NF	NQ	NF	NQ	NF	NQ	NF	Kristofferson and Carder 1980
1966	18160	16783	NQ	NF	NQ	NF	NQ	NF	NQ	NF	NQ	NF	NQ	NF	Kristofferson and Carder 1980
1967	45000[d]	27669	45000[d]	NF	45000[d]	NF	45000[d]	NF	NQ	NF	NQ	NF	NQ	NF	Kristofferson and Carder 1980
1968	45000[d]	34296	45000[d]	6464	45000[d]	2614	45000[d]	NF	NQ	NF	NQ	NF	NQ	NF	Kristofferson and Carder 1980
1969	45000[d]	22680	45000[d]	NF	45000[d]	25855	45000[d]	NF	NQ	NF	NQ	NF	NQ	NF	Kristofferson and Carder 1980
1970	Closed	NF	45000[d]	5878	45000[d]	26203	45000[d]	2420	NQ	NF	NQ	NF	NQ	NF	Kristofferson and Carder 1980
1971	Closed	NF	45000[d]	NF	45000[d]	10433	45000[d]	19051	22700	12814	NQ	NF	NQ	NF	Kristofferson and Carder 1980
1972	Closed	NF	NQ	NF	9100	6477	18160	20994	11350	12524	NQ	NF	NQ	NF	Kristofferson and Carder 1980
1973	18160	9618	NQ	NF	9100	1918	18160	9657	11350	7239	NQ	NF	NQ	NF	Kristofferson and Carder 1980
1974	11340	12540	NQ	NF	Closed	NF	11350	8125	11350	6956	NQ	NF	NQ	NF	Kristofferson and Carder 1980
1975	11340	12261	NQ	NF	Closed	NF	Closed	NF	11350	10357	NQ	NF	6800	8231	Kristofferson and Carder 1980
1976	11340	13628	NQ	NF	9100	2780	Closed	NF	13600	12679	NQ	NF	6800	9437	Kristofferson and Carder 1980
1977	11340	15897	4500	3254	4500	4624	6800	1519	13600	20796	11350	13649	6800	7563	Kristofferson and Carder 1980
1978	11340	14584	6800	8416	4500	5734	6800	8416	13600	9118	11350	8135	6800	13442	Kristofferson and Carder 1980
1979	14500	15806	9100	11816	6800	7316	9100	10845	9100	7177	11350	1736	13600	12260	Carder 1981
1980	14500	10519	9100	7497	6800	7481	9100	9151	9100	6630	11350	3377	13600	14501	Carder 1981
1981	14500	14283	9100	8638	6800	7009	9100	8724	9100	5744	6800	2836	13600	13320	Carder 1983
1982	14500	14234	9100	9045	6800	6848	9100	8918	9100	8864	6800	NF	13600	5711	Carder 1983
1983	14500	14840	9100	8831	6800	6825	9100	9106	9100	9046	6800	NF	13600	12966	Carder and Low 1985
1984	14500	14500	9100	8814	6800	7306	9100	9876	9100	8953	6800	NF	13600	13515	Carder and Low 1985
1985	14500	14524	9100	9286	6800	6448	9100	9056	4500	5598	4500	NF	13600	11584	Carder 1988
1986	14500	14349	9100	9123	6800	6830	9100	8243	4500	4180	4500	NF	13600	12076	Carder 1988
1987	14500	14661	9100	8668	6800	6875	9100	9553	4500	4525	4500	NF	13600	13686	Carder and Stewart 1989
1988	14500	14834	9100	8570	6800	6808	9100	9425	6000	6544	4500	NF	13600	11820	Carder and Stewart 1989
1989	14500	13565	9100	9176	6800	6857	9100	9184	6000	5969	4500	NF	13600	12866	Carder 1991
1990	14500	15294	9100	9318	6800	6971	9100	8938	6000	6371	4500	NF	13600	12865	Carder 1991

Table 1 cont.

Year	Ekalluk		Paliryuak		Halovik		Lauchlan		Ellice		Perry		Jayco		Source[a]
	Quota (kg)	Harvest (kg)	Quota (kg)	Harvest (kg)	Quota (kg)	Harvest (kg)	Quota (kg)	Harvest (kg)	Quota (kg)	Harvest (kg)	Quota (kg)	Harvest (kg)	Quota (kg)	Harvest (kg)	
1991	Closed	NF	9100	8953	6800	6354	9100	8807	8000	7971	6500	601	15600	2226	Carder 1993
1992	7500	NF	9100	8884	6800	6872	9100	9320	8000	NF	6500	NF	15600	NF	Carder 1993
1993	7500	1480	9100	6579	6800	5939	9100	9306	8000	8016	6500	NF	15600	15411	Carder 1995
1994	20000	1640	9100	NF	5000	3859	9100	NF	8000	7175	6500	NF	17000	16287	Carder 1995
1995	20000	5831	9100	NF	5000	5336	2400	1799	8000	9420	6500	NF	17000	15695	FMHIS
1996	20000	10210	9100	NF	5000	4909	2400	2352	8000	4502	6500	NF	17000	16914	FMHIS
1997	20000	14328	9100	NF	5000	4995	2400	900	8000	NF	6500	NF	17000	10585	Day and de March 2004
1998	20000	19825	9100	NF	5000	5143	2400	1430	8000	NF	6500	NF	17000	17070	Day and de March 2004
1999	20000	14581	9100	5677	5000	5120	2400	2740	8000	4497	6500	NF	17000	17094	Day and de March 2004
2000	20000	16932	9100	5808	5000	5205	2400	NF	8000	NF	6500	NF	17000	17312	Day and de March 2004
2001	20000	16244	9100	5766	5000	5426	2400	436	8000	NF	6500	NF	17000	16349	FMHIS
2002	20000	17566	9100	9044	5000	4968	2400	NF	8000	NF	6500	NF	17000	17434	FMHIS
2003	14500	16481	9100	8005	6800	5718	9100	1543	8000	NF	6500	NF	13600	17215	FMHIS
2004	14500	14695	9100	9006	6800	6914	9100	3267	8000	NF	6500	NF	13600	7573	FMHIS
2005	14500	13717	9100	8827	6800	6617	9100	2913	8000	NF	6500	NF	13600	2613	FMHIS
2006	20000	14265	9100	7476	5000	7603	2400	8814	8000	NF	6500	NF	17000	12781	FMHIS
2007	20000	10586	9100	8736	5000	6786	2400	8666	8000	NF	6500	NF	17000	8633	FMHIS
2008	20000	10944	9100	4855	5000	7587	2400	2367	8000	NF	6500	NF	17000	14327	FMHIS
2009	20000	12666	9100	8657	5000	4555	2400	NF	8000	NF	6500	NF	17000	6514	FMHIS

a = harvest and quota from 1960-1994 were compiled from the various data reports. Harvest and quota from 1995 to 2009 (with the exception of 1997-2000) are from the Fisheries Management Harvest informaion System (FMHIS) using a 1.25 (pre-2005) or 1.2 (2005 and on) round to to dressed weight conversion.
b = no quota officially assigned, but two Inuit families supported by the Ekaluktutiak Coop harvested this amount (Barlishen and Webber 1973).
c = no quota officially assigned.
d = Wellington Bay area quota.

Table 2. Sampling dates and type of fishing gear used (G=Gillnets, W=Weirs or B=both) for Cambridge Bay commercially caught anadromous Arctic Char.

Year	Ekalluk River			Ellice River			Halovik River			Jayco River			Lauchlan River			Paliryuak River		
	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept
1971					G 24													
1972		G 30			G 24-27			G 14-23					G 15	G 2-11				
1973														G 27-28	G 2-3			
1974		G 22-24			G 24									G 22-25				
1975													G 5					
1976		G 28-30			G 26-29	G 1-2		G 28			G 26-31	G 1						
1977		G 22-24			G 22-29		G 6-13						G 7-9			G 6-15		
1978		G 20-29			G 24-31	G 3-5	G 22-28				G 4-7	G 1-5	G 28-30					
1979		G 26-27			G 24-30	G 4	G 15-22			G 23-28	G 2		G 15-24			G 15-20		
1980		G 25-29			G 31	G 1-4	G 10-18			G 10-20		G 1-8	G 10-20			G 10-23	G 26-31	G 1-8
1981		G 25-29			G 31	G 1-6	G 8-19			G 11-19		G 5-9	G 9-26	G 25-27		G 8-18		
1982		G 22-29			G 17-30		G 10-16					G 5-10	G 10-17	G 23-27		G 10-14		
1983		G 21-26			G 20-26		G 7-20			G 7-18		W 2-4		G 17-30		G 7-20	G 27	
1984		G 21-25			G 22-29	G 1	G 10-16			G 9-17	G 30	G 4-5	G 10-14	G 20		G 9-14	G 23-30	
1985		G 24-31			G 24-25		G 9-13			G 8-17			G 8-19			G 9-23	G 31	
1986		G 21-27			G 27-31		G 14-15				G 30-31		G 14-19			G 14-15		
1987		G 20-26			G 26-29	G 3	G 14-25					G 2-3	G14-26			G 13-23		
1988		G 22-29			G 25-30	G 1	G13-21					G 10-17	G 10-16			G 12-22		
1989		G 20-25			G 23-26		G 10-16				G 30-31	G 2-4	G 10-17			G 10-12		
1990		G 16-22			G 24-27						G 31	G 1-10	G 18-19			G 18-21		
1991		G 24-25			G 23-30	G 1	G 14-17					G 8-9	G 14-17			G 13-17		
1992		G 27-28					G 17-20						G 15-18			G 17-19		
1993		G 26-29			G 20-29		G 12-17				G 1, 31	G 1-8	G 11-13			G 11-17		
1994		W 27	W 4		G 21-27			W 28-31	W 1-5			W 1-8						
1995		W 30-31	W 1		G 21-25			G 26-28				G 5-10						
1996		G 25-30			G 18-24			W 18-24				W 2-7						
1997		G 15-22	G 3-5					W ?				W 3-8		G ?				
1998		G 21-28						W 24-27				W 1-12						
1999		G 26-31	1		G 25-27			W 23-25				W 3-8						
2000		G ?						W ?				W ?						
2001		G ?						G ?				W ?						
2002		G 23										W 5						
2003		G ?						W ?										
2004		G 26	G 1-2					W 25-31				W 13-14		G 21-26		G 20-24		
2005		G 25, 31	G 1-7					W 24-25				B 9-12		G 18, 24		G 5		
2006								B 13-17					G 17-26			G 11-15		
2007		G 28-31						W 20-27				W 7-12	G 20-28			G 20-27		
2008		G 26, 29	G 1-7					W 12-25				W 6-16	G 19-23			G 16-23		
2009		G 30	G 2-8					W 30	W 1-2			W 14-17				G 13-16		

Table 3. Weir enumerations of fall upstream Arctic Char (Salvelinus alpinus) migrations in the Cambridge Bay area, Nunavut.

Year	Location				
	Ekalluk [a] River	Jayco [a] River	Halovik [a] River	Lauchlan [a] River	Freshwater [b] Creek
1979	183,203	.	.	.	.
1980	.	33,388 [c]	.	.	.
1981	.	138,795	21,214	.	.
1982	.	.	.	.	9,961
1983	.	.	.	10,850	.
1988	.	.	.	.	36,933
1991	.	.	.	.	39,559

[a] from McGowan (1990)
[b] from McGowan and Low (1992)
[c] incomplete count

Table 4. Cambridge Bay Arctic Char (Salvelinus alpinus) fisheries risk levels. Strong modal age classes (greater than or equal to 20 % of the harvest) by fishing period and fishery with a level of risk of overexploitation if harvest rates continue at present levels are shown.

Location	Period	Strong Modal Age Classes	Risk Level (over 10 years)
Ekalluk	1971-1980	12-16	Low to Moderate
	1981-1990	12-14	
	1991-2000	11-14	
	2001-2009	11-14	
Ellice	1971-1980	8-13	Moderate
	1981-1990	7-12	
	1991-2000	8-11	
	2001-2009	Not fished	
Halovik	1971-1980	11-15	Low
	1981-1990	13-17	
	1991-2000	11-15	
	2001-2009	11-14	
Jayco	1971-1980	15-16	Low
	1981-1990	13-16	
	1991-2000	10-15	
	2001-2009	11-14	
Lauchlan	1971-1980	8-14	Low
	1981-1990	11-16	
	1991-2000	12-13	
	2001-2009	11-15	
Paliryuak	1971-1980	Not fished	Low
	1981-1990	12-15	
	1991-2000	13	
	2001-2009	12-14	

Table 5. Age and size statistics for maturity stages of Arctic Char from the Cambridge Bay area, Nunavut. Data are combined for all char sampled by commercial weir, experimental weir and 140 mm stretched mesh gillnets at the Paliryuak River (1979, 1980), Lauchlan River (1974, 1978, 1983), Jayco River (1975, 1978, 1980, 1981, 2005), Halovik River (1972, 1978, 1981, 2006), Ellice River (1978) and Ekalluk River (1978, 1979, 1993, 1994).

Sex	Maturity Stage	Number Sampled	% by Sex	Age (years)			Fork Length (mm)			Round Weight (grams)		
				Mean	± 95% Confidence Interval	Range	Mean	± 95% Confidence Interval	Range	Mean	± 95% Confidence Interval	Range
F	Immature	518	64.2	10.7	10.3 – 11.0	2 - 31	521.1	510 - 532	215 - 794	1,815	1,714 – 1,916	75 – 5,275
F	Resting	260	32.2	13.5	13.2 – 13.8	5 - 21	656.6	648 - 665	380 - 793	3,453	3,326 – 3,579	520 – 6,125
F	CYSp*	18	2.2	15.1	13.9 – 16.2	12 - 19	724.2	682 - 766	597 - 840	4,130	3,482 – 4,777	2250 – 6,105
F	Ripe	9	1.1	13.3	12.2 - 14.4	11 - 15	560.9	509 - 613	485 - 700	1,808	1,354 – 2,263	1,200 – 3,050
F	Spent	2	0.3	**	**	11, 14	**	**	571, 715	**	**	2,400, 4,450
Total No. Females Sampled = 807												
M	Immature	687	70.5	11.7	11.5 – 12.0	3 - 21	587.7	578 - 597	208 - 836	2,472	2,373 – 2,570	100 – 6,350
M	Resting	246	25.2	13.4	13.2 – 13.7	7 - 23	689.8	681 - 699	470 - 900	4,000	3,841 – 4,158	1250 – 7,645
M	CYSp*	38	3.9	14.4	13.5 – 15.3	10 - 25	681.2	647 - 715	491 - 889	3,312	2,807 – 3,817	450 – 6,295
M	Spent	2	0.2	**	**	10, 14	**	**	586, 766	**	**	2,000, 5,000
Total No. Males Sampled = 973												
Overall Total No. Sampled for Both Sexes = 1780							Overall Total Percentages, Female = 45.3, Male = 54.7					

CYSp* = Current Year Spawner
** sample size of only two, therefore not calculated

Table 6. Sampling regime, maturity status and mean round weight of Arctic Char sampled from the commercial harvest of the Cambridge Bay commercial char fishery, Nunavut.

Location	Year	Sample Size	Sex	Maturity	Number Sampled	Percent by Sex	Mean Round Weight
Ekalluk	1978	173	F	Imm	52	98.1	3152
				Mat	1	1.9	2800
			M	Imm	118	98.3	3416
				Mat	2	1.7	3600
	1979	154	F	Imm	32	41.6	1662
				Mat	45	58.4	3276
			M	Imm	22	28.6	1214
				Mat	55	71.4	3850
	1993	122	F	Imm	35	61.4	2442
				Mat	22	38.6	3995
			M	Imm	34	52.3	2497
				Mat	31	47.7	4207
	1994	49	F	Imm	4	23.5	2938
				Mat	13	76.5	3835
			M	Imm	11	34.4	2709
				Mat	21	65.6	4329
Ellice	1978	98	F	Imm	49	96.1	2350
				Mat	2	3.9	3325
			M	Imm	47	100	2586
				Mat	0	0	NA
Halovik	1972	43	F	Imm	13	68.4	636
				Mat	6	31.6	1856
			M	Imm	16	66.7	738
				Mat	8	33.3	2531
	1978	121	F	Imm	38	62.3	2766
				Mat	23	37.7	3324
			M	Imm	37	61.7	3415
				Mat	23	38.3	3854
	1981	36	F	Imm	20	100	760
				Mat	0	0	NA
			M	Imm	15	93.8	780
				Mat	1	6.3	3100
	2006	76	F	Imm	0	0	NA
				Mat	55	100	4420
			M	Imm	5	23.8	3614
				Mat	16	76.2	5141

Table 6. Continued. Sampling regime, maturity status and mean round weight of Arctic Char sampled from the commercial harvest of the Cambridge Bay commercial char fishery, Nunavut.

Location	Year	Sample Size	Sex	Maturity	Number Sampled	Percent by Sex	Mean Round Weight
Jayco	1975	173	F	Imm	101	100	1113
				Mat	0	0	NA
			M	Imm	72	100	1527
				Mat	0	0	NA
	1978	40	F	Imm	2	100	4350
				Mat	0	0	NA
			M	Imm	37	97.4	3509
				Mat	1	2.6	3400
	1980	73	F	Imm	21	77.8	1062
				Mat	6	22.2	2475
			M	Imm	40	87	1542
				Mat	6	13	2917
	1981	156	F	Imm	59	86.8	1112
				Mat	9	13.2	1808
			M	Imm	74	84.1	1718
				Mat	14	15.9	2220
	2005	90	F	Imm	0	0	NA
				Mat	48	100	2903
			M	Imm	0	0	NA
				Mat	42	100	3693
Lauchlan	1974	50	F	Imm	12	37.5	2297
				Mat	20	62.5	2536
			M	Imm	16	88.9	2836
				Mat	2	11.1	4850
	1978	136	F	Imm	29	93.5	2897
				Mat	2	6.5	3325
			M	Imm	101	96.2	3370
				Mat	4	3.8	3763
	1983	125	F	Imm	43	72.9	1292
				Mat	16	27.1	4569
			M	Imm	34	51.5	1160
				Mat	32	48.5	4923
Paliryuak	1979	15	F	Imm	1	33.3	1300
				Mat	2	66.7	2650
			M	Imm	2	16.7	1625
				Mat	10	83.3	3290
	1980	50	F	Imm	7	26.9	693
				Mat	19	73.1	3349
			M	Imm	6	25	1163
				Mat	18	75	3328

FIGURES

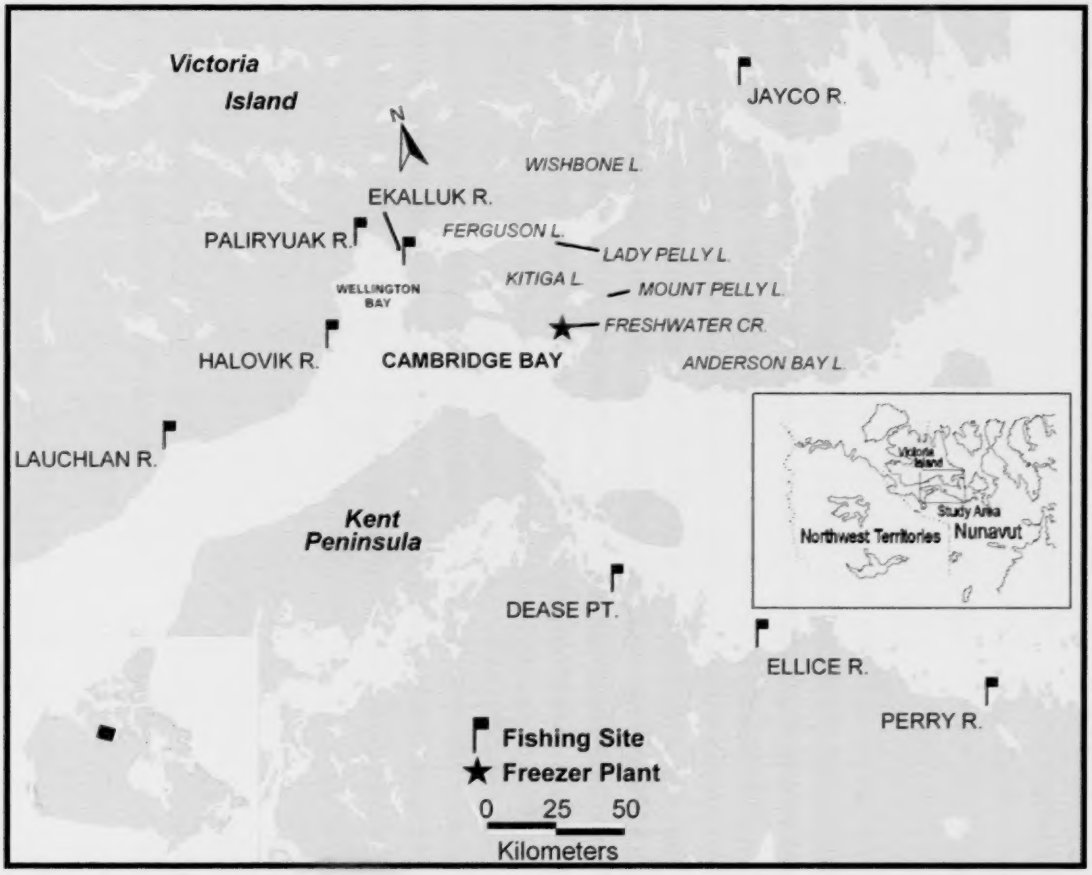


Figure 1. Cambridge Bay area Arctic Char fishing sites, Nunavut (after Kristofferson 2002, Kristofferson and Berkes 2005).

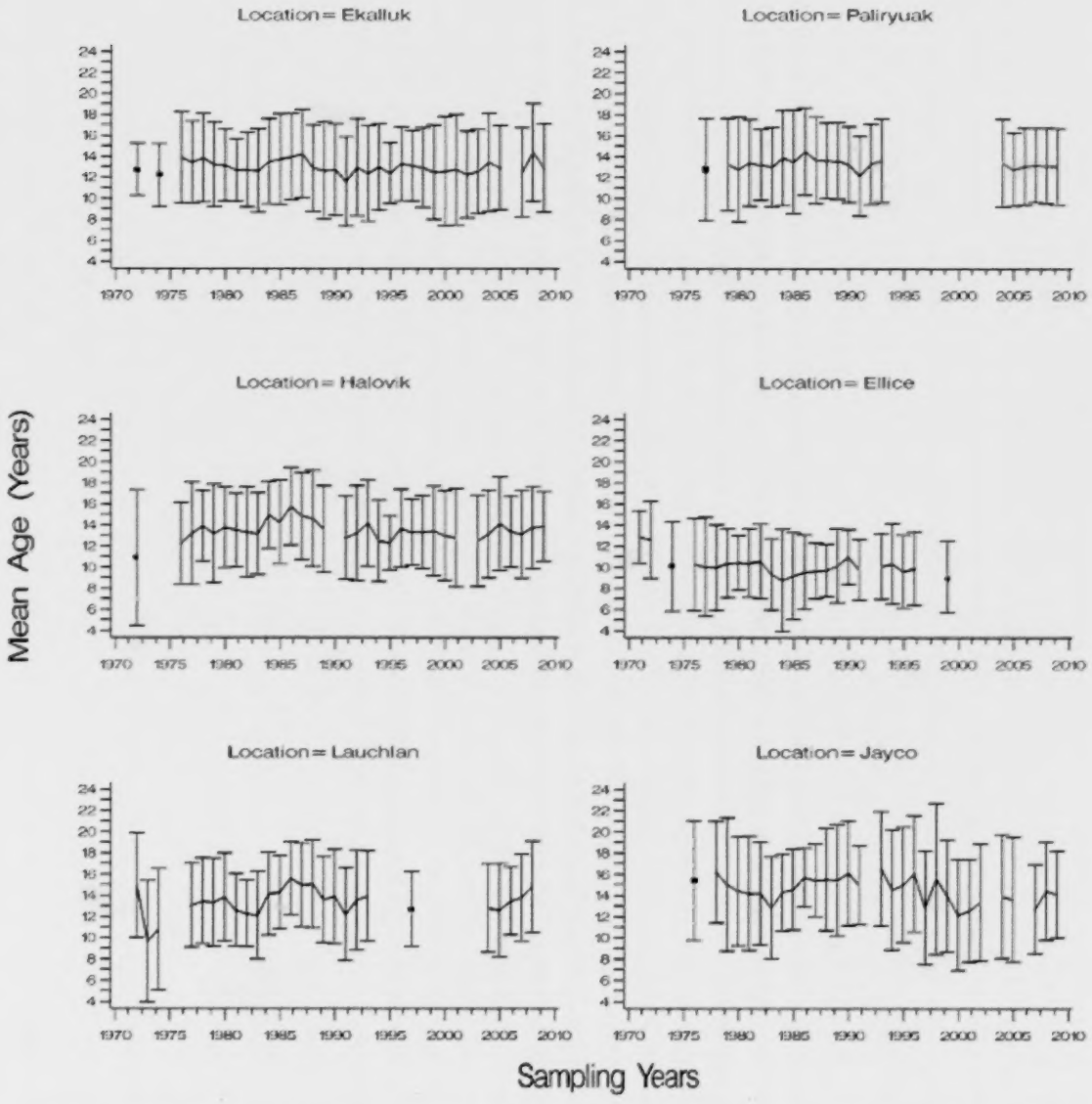


Figure 2. Mean age (± 2 standard deviations) of anadromous Arctic Char sampled from the commercial fishery harvest, Cambridge Bay, Nunavut.

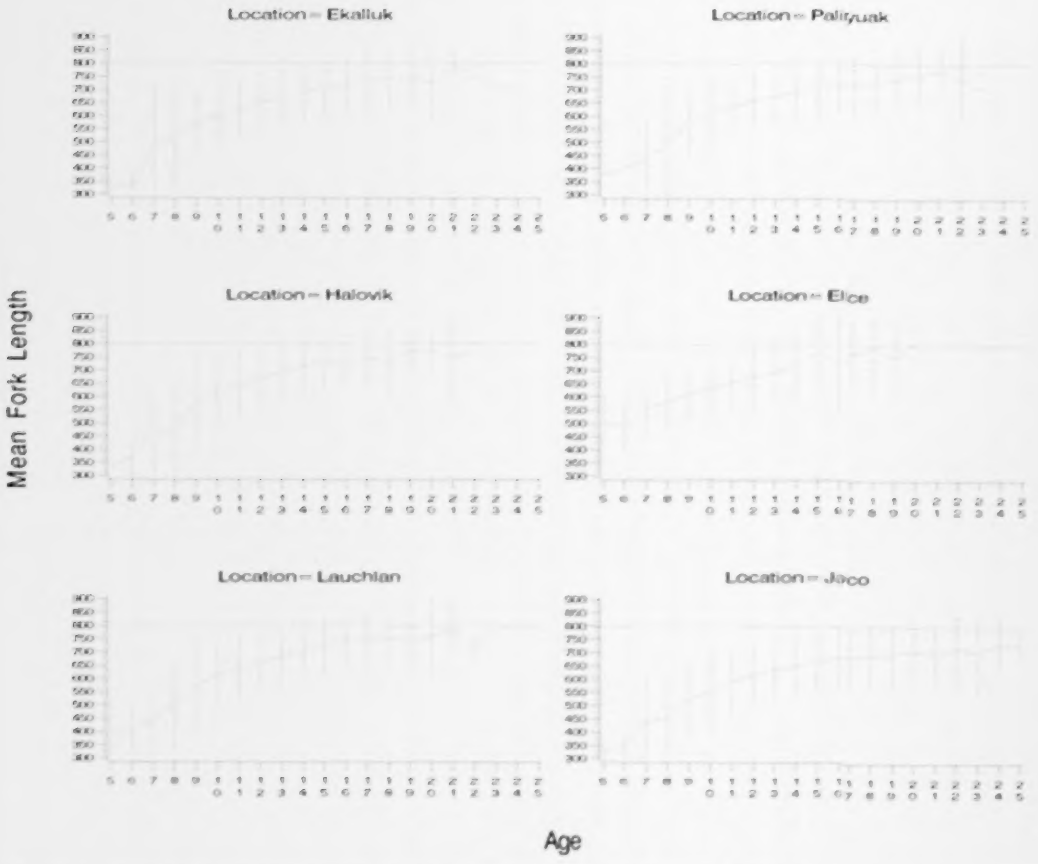
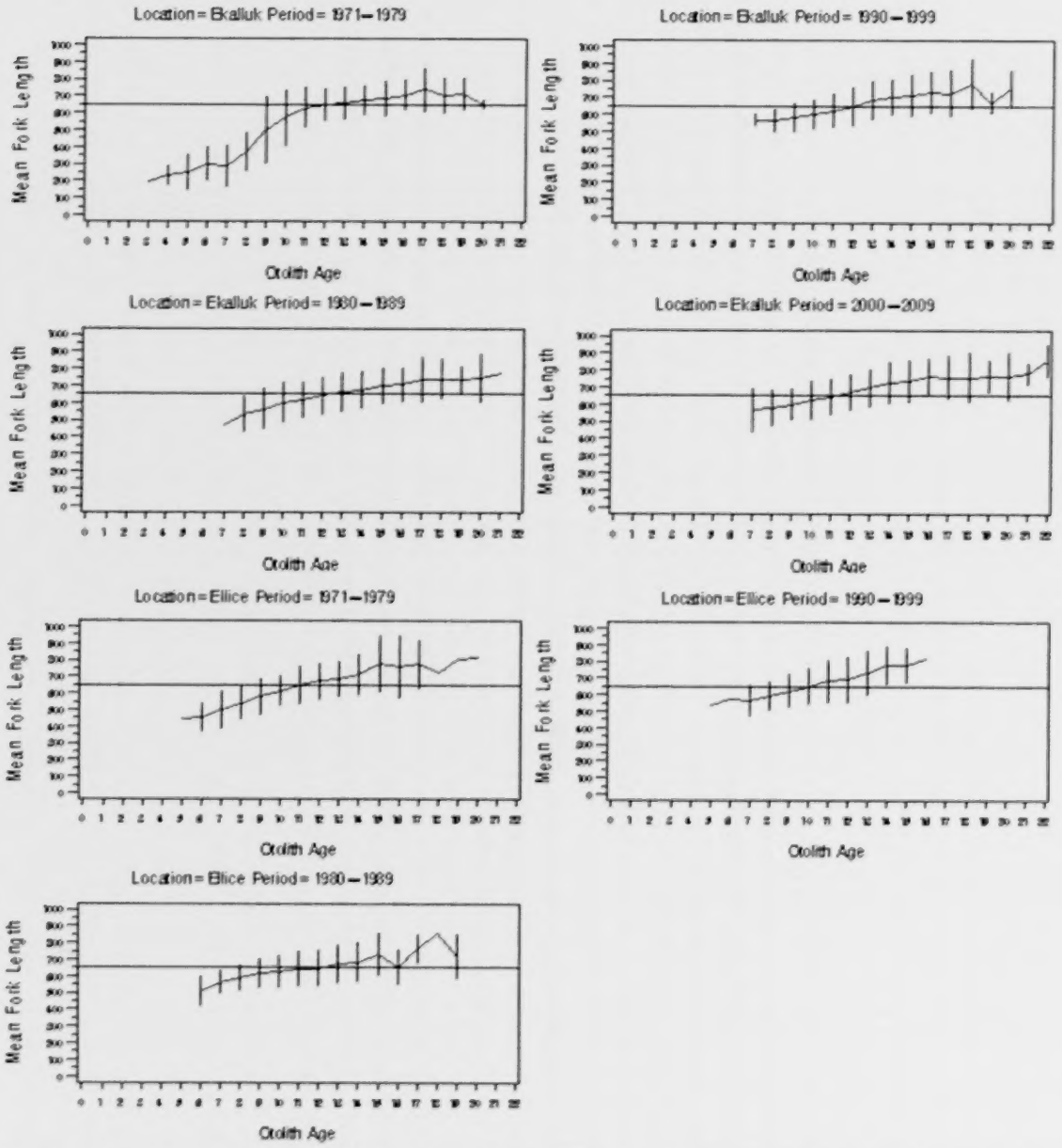


Figure 3. Plots of mean fork length at age (± 2 standard deviations), 1971-2003 data pooled, for anadromous Arctic Char sampled from the commercial fishery, Cambridge Bay, Nunavut (after Day and de March 2004)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Location = Ekalluk Period = 1990—1999
Location = Ekalluk Period = 1980—1989
Location = Ekalluk Period = 2000—2009
Location = Ellice Period = 1971—1979
Location = Ellice Period = 1990—1999
Location = Ellice Period = 1980—1989
Mean Fork Length
Otolith Age

Figure 4. Plots of mean fork length at age (± 2 standard deviations) by period for anadromous Arctic Char sampled from the Ekalluk and Ellice rivers commercial fisheries, Cambridge Bay, Nunavut. The Ellice River was not fished from 2000-2009.

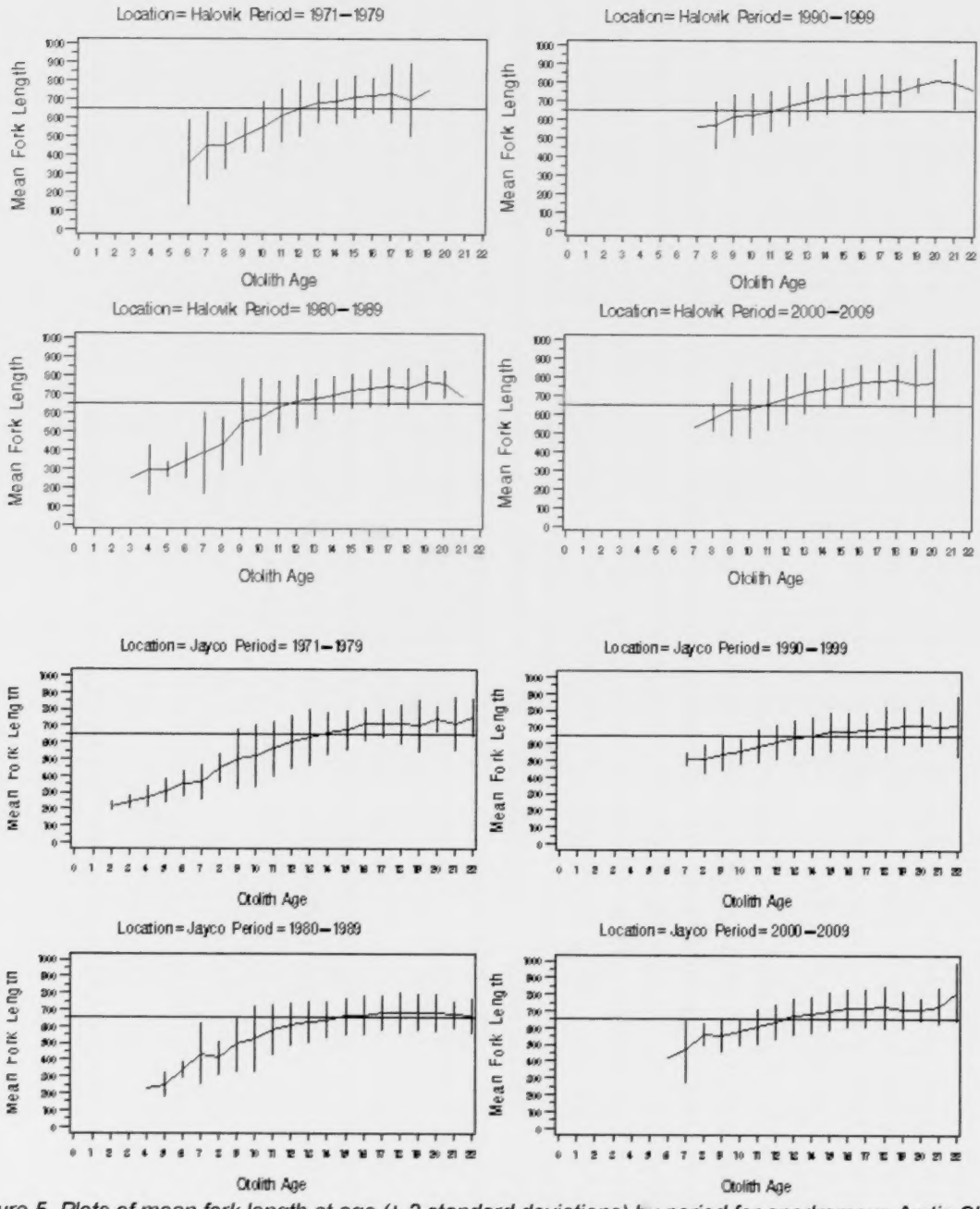
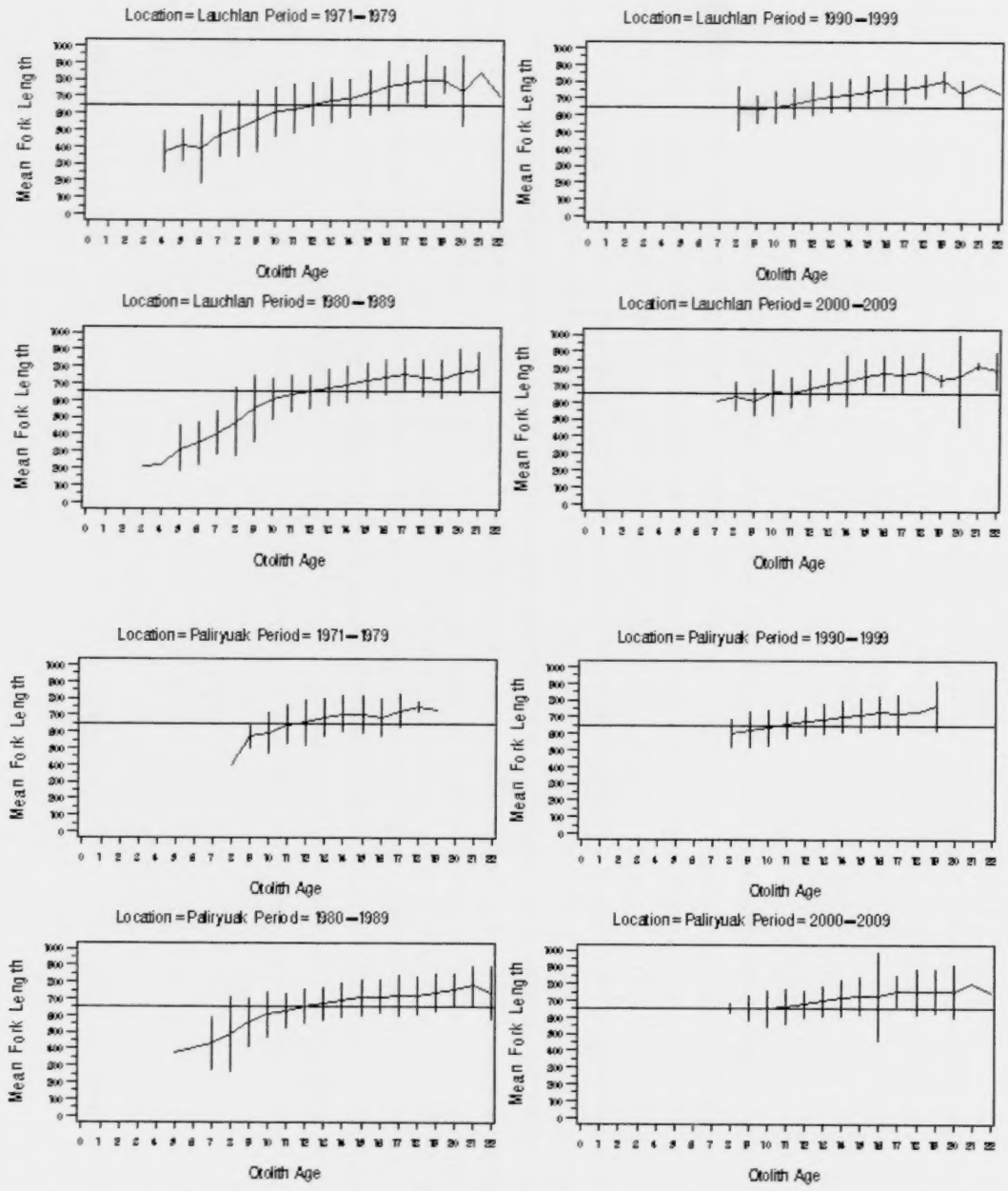


Figure 5. Plots of mean fork length at age (± 2 standard deviations) by period for anadromous Arctic Char sampled from the Halovik and Jayco rivers commercial fisheries, Cambridge Bay, Nunavut.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Location = Lauchlan Period = 1990—1999
Location = Lauchlan Period = 1980—1989
Location = Lauchlan Period = 2000—2009
Location = Paliryuak Period = 1971—1979
Location = Paliryuak Period = 1990—1999
Location = Paliryuak Period = 1980—1989
Location = Paliryuak Period = 2000—2009
Mean Fork Length
Otolith Age

Figure. 6. Plots of mean fork length at age (± 2 standard deviations) by period for anadromous Arctic Char sampled from the Lauchlan and Paliryuak rivers commercial fisheries, Cambridge Bay, Nunavut.

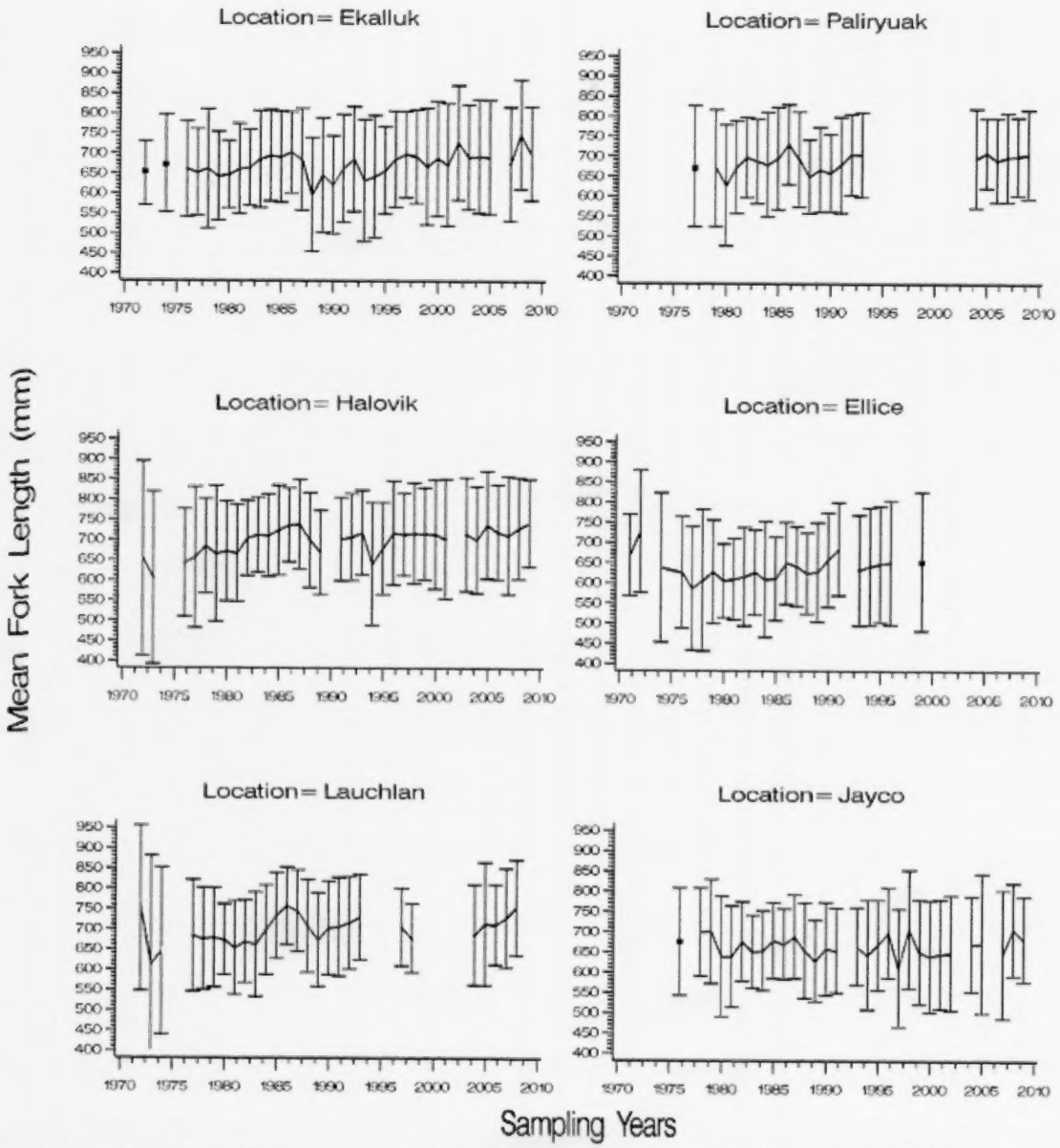

Figure 7. Mean fork length (± 2 standard deviations) of anadromous Arctic Char sampled from the commercial fishery harvest, Cambridge Bay, Nunavut.

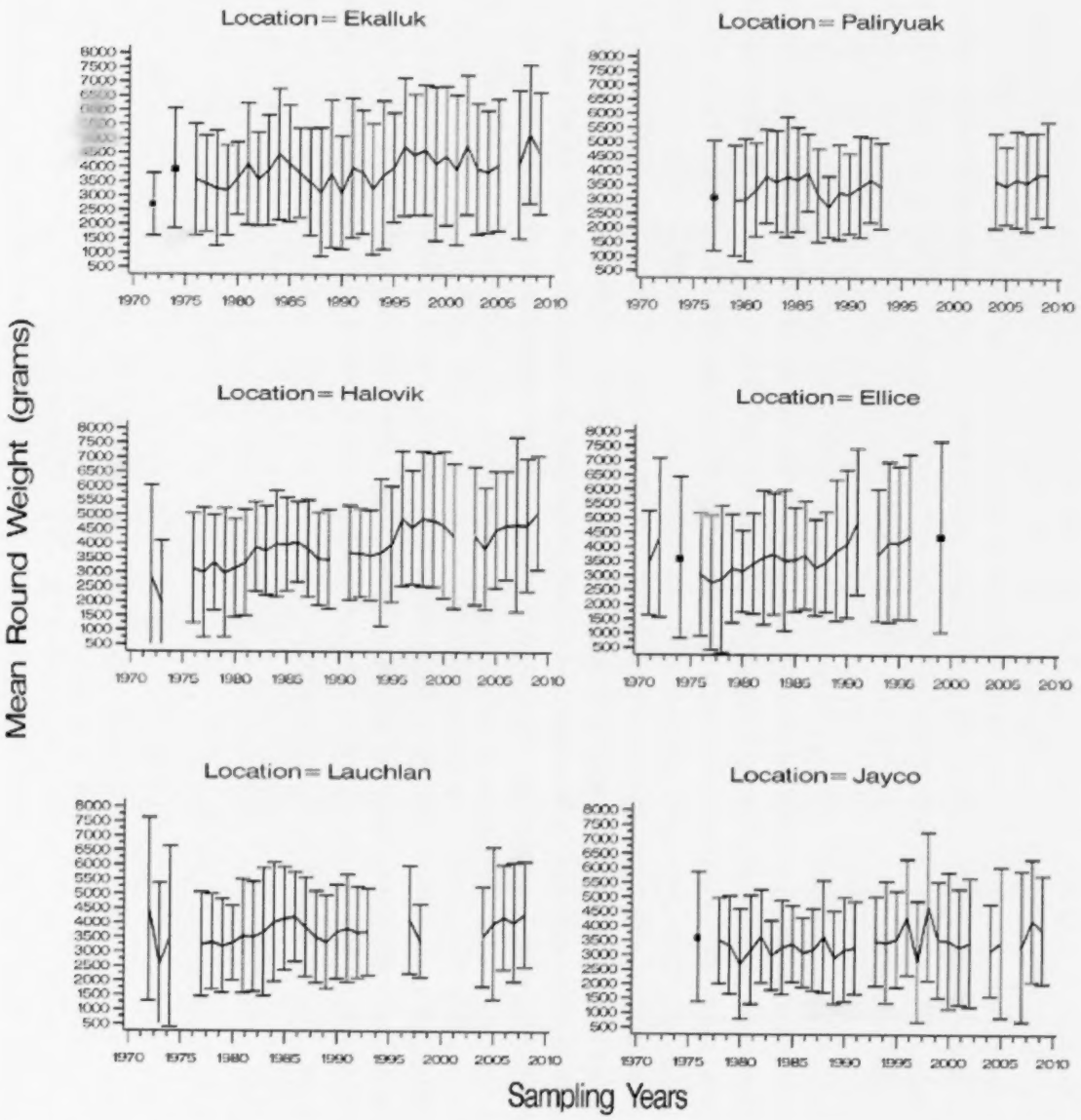

Figure 8. Mean round weight (± 2 standard deviations) of anadromous Arctic Char sampled from the commercial fishery harvest, Cambridge Bay, Nunavut.

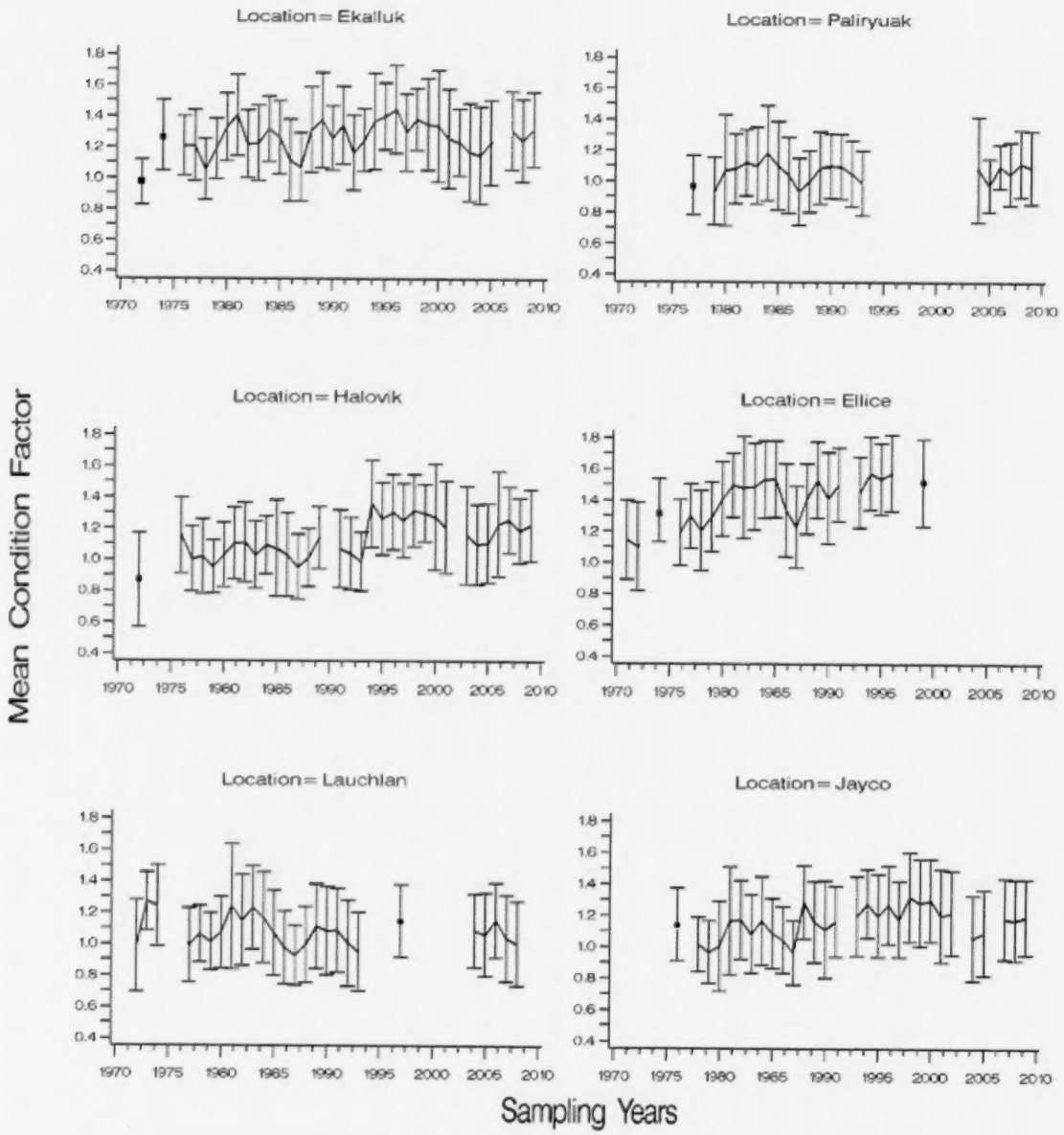

Figure 9. Mean condition factor (± 2 standard deviations) of anadromous Arctic Char sampled from the commercial fishery harvest, Cambridge Bay, Nunavut.